

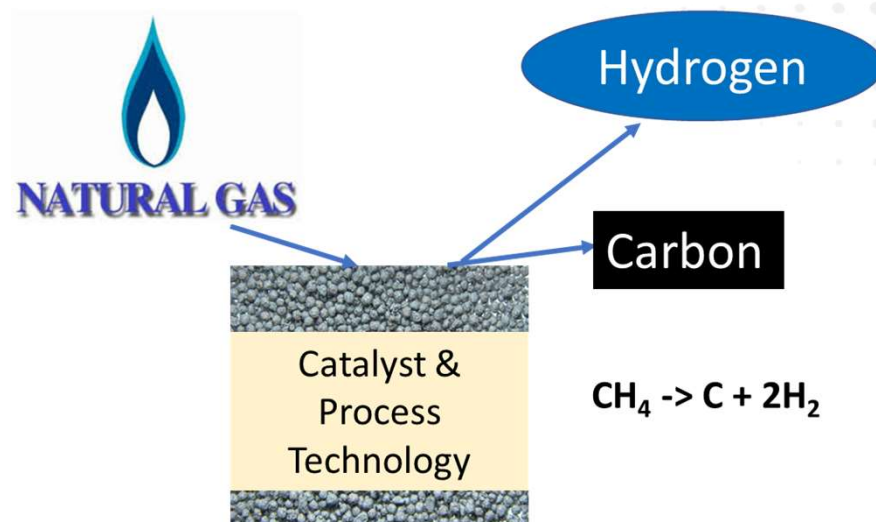
Production of carbon and hydrogen from natural gas via catalytic pyrolysis



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Project Vision

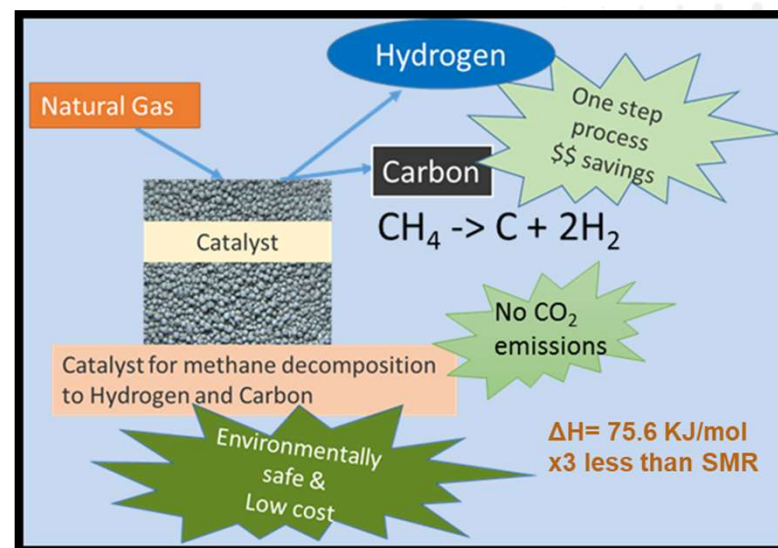
We are solving issues with catalytic pyrolysis of methane by developing a low cost, durable catalyst with high methane conversion to H₂ that also produces valuable carbons.



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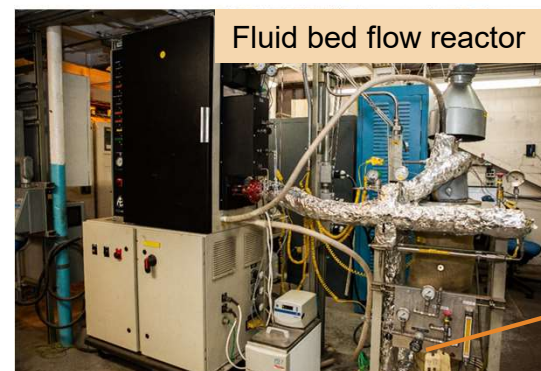
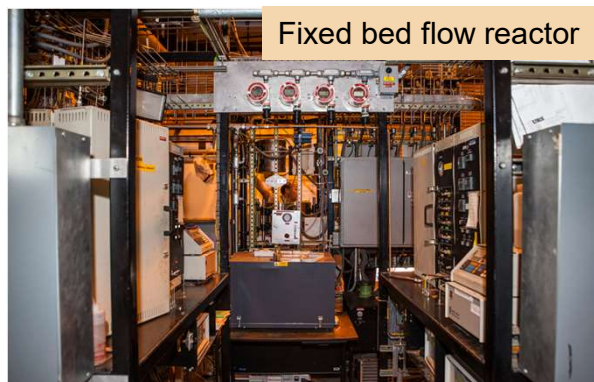
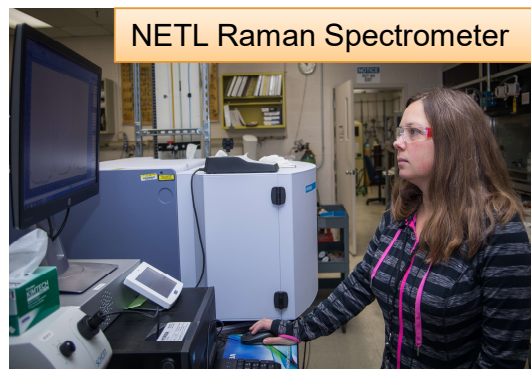
The Concept - Catalytic methane pyrolysis (CMP)

- ▶ Catalyst decomposes methane to produce valuable products, H₂ and carbon
- ▶ Operates at 650-750°C and mildly endothermic
- ▶ Project focus – Develop thermo catalytic H₂ production process that is more economical than current commercial SMR H₂ production process
- ▶ Final project targets (not funded)
 - Construct a prototype reactor
 - High pressure reactor with catalyst feed capability at high temperature
 - catalyst loading > 3 Kg and I.D> 9 cm and >186 cm height
 - Continuous operation in the prototype reactor to validate catalyst lifetime that satisfies < 1.5 \$ / kg H₂
 - Conceptual design of a pilot plant to demonstrate the techno-economic merits



The Team

- ▶ **National Energy technology lab/U.S. Department of Energy –**
 - Develop/prepare catalysts, conduct fixed bed and fluidized bed testing, material characterization



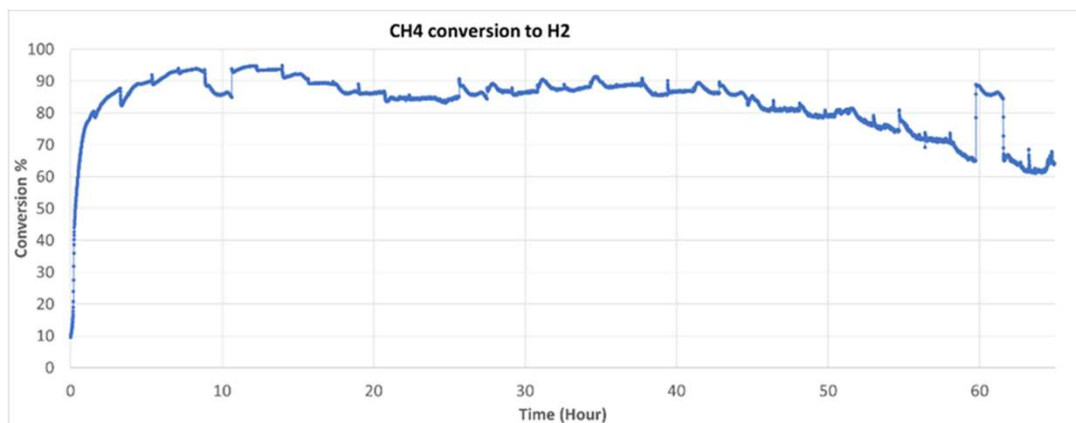
- ▶ **Industrial partner Birla carbon USA**
 - Corporative research agreement with NETL/DOE funded by EERE
 - Analyze carbons, application tests and techno economic analysis

Main results and concept updates from last year

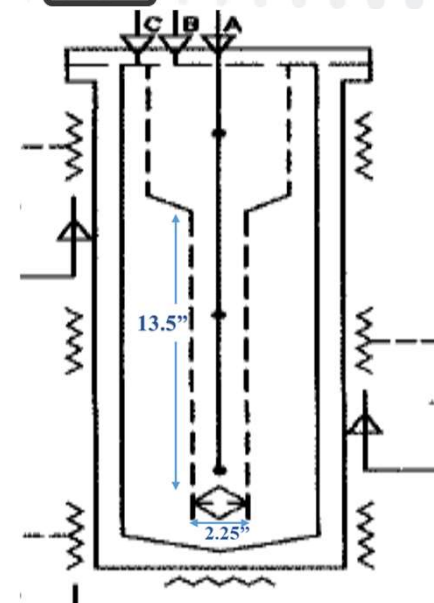
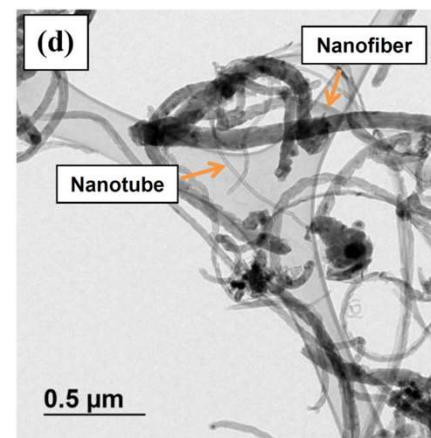
- long term fluidized bed tests with NETL developed catalyst



Percentage of CH₄ conversion to H₂ during 65 hr. fluid bed methane pyrolysis test with NETL catalyst (425 g) at 700 C



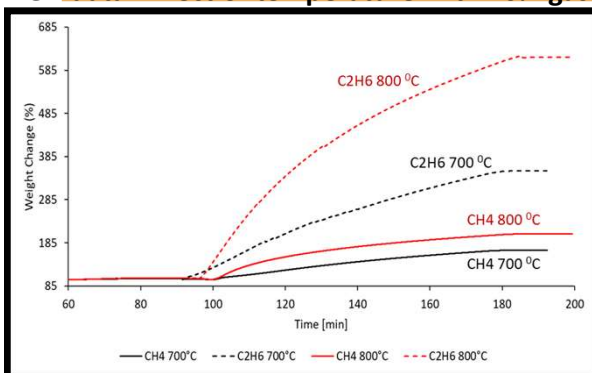
- High methane conversion 80-90% to H₂ for about 50 hrs. and over 60% for 65 hrs.
- Carbon was collected continuously in the filters during the test
- Carbon were valuable nano fibers and nano tubes



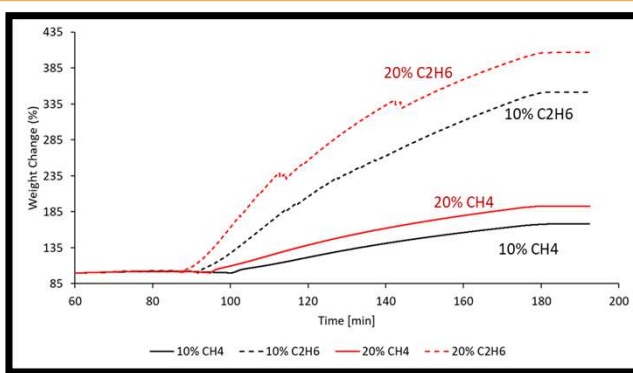
Main results and concept updates from last year

Effect of ethane on methane pyrolysis

TGA data -Effect of temperature with 10% gas



TGA data- Effect of concentration at 700 °C

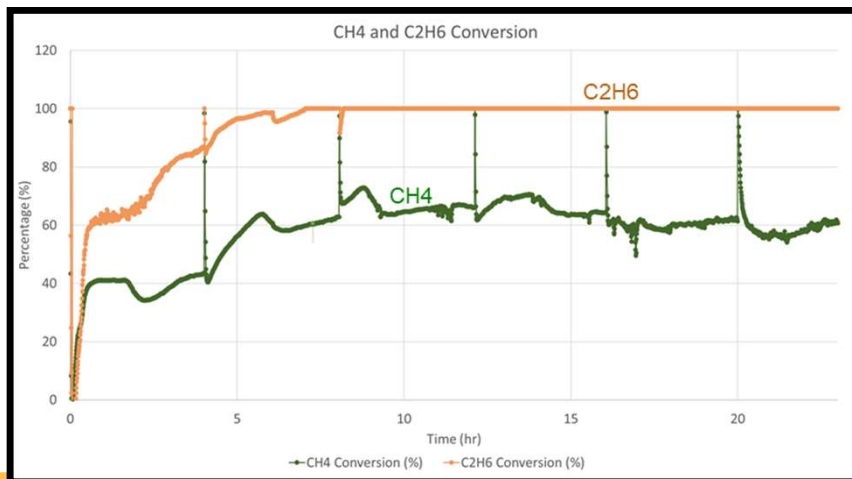


TGA methane and ethane pyrolysis comparisons

- Ethane decomposition rates are significantly higher than the rates with methane
- Higher temperature has a significant increase in ethane decomposition
- Concentration has some effect but not significant as temperature effect

Fluid bed data with methane and ethane (4:1 conc. ratio) at 700 °C

- 100 % conversion of ethane to H₂
- Higher conversion of ethane than methane
- Higher H₂ effluent concentration



Additional results

- Evaluated Low-cost formulations: cost 4 times less than the original
 - Slightly lower but acceptable TGA performance
- Preliminary systems analysis
 - Heat required for the process can be generated using less than 20% product H₂ avoiding CO₂ emissions
 - Carbon selling price plays a major role in the break-even-H₂ selling price.
 - H₂ selling price better than SMR (<\$2/kg) even with low carbon selling prices (> \$1/kg)
 - Catalyst recycle is not necessary at a catalyst price of \$8/kg or less.
 - Advantages over SMR –
 - Increased efficiency and lower net energy requirements coupled with lower CO₂ emissions
- Lower breakeven H₂ selling price**

Challenges and Potential Technical Partnerships



► Challenges

- Carbon purity
- Catalyst disposal procedures and cost
- Gas separations (e.g., methane and H₂) to obtain 100% H₂
- Performance evaluation in a prototype reactor with continuous H₂ production
- Scale up and commercialization

- **Current industrial partner Birla carbon USA - primary interest in carbon products**
- **Need potential partners to commercialize the process to utilize hydrogen**

Timeline

Task	Scheduled date (Start date –July 31, 2020)	Status
Conduct preliminary ASPEN analysis	4 months	Complete
Performance with low-cost formulations	6 months	Complete
Evaluation of feed gas composition (ethane and propane)	8 months	Partially complete
Optimization of reaction conditions –particle size, P, T,	8 months	Partially complete
Economic Evaluation	12 months	In progress

- Final goal - Demonstrate the technology for continuous H₂ production with an industrial partner in a pilot scale unit